Memorandum

Date: May 8, 2018

To: City of Wichita

From: Burns & McDonnell

Subject: Northwest Water Treatment Facility: Process and Site Technical Memo

SECTION 1 INTRODUCTION

The City of Wichita currently operates a Main Water Treatment Plant (MWTP) located in the Sim Park area. This treatment facility operates as a Central Plant with a capacity of 130 million gallons per day (MGD) and an East Plant with a capacity of 30 MGD. The East Plant was constructed around 1939 and the Central Plant was constructed around 1953. The entire facility was partially rehabilitated and upgraded in 1992.

The City has requested that treatment alternatives be evaluated and recommended for a new 120 MGD firm capacity Northwest Water Treatment Facility (NWWTF). The three primary source waters for the facility include groundwater from the Equus Beds Wellfield, surface water from Cheney Reservoir which receives coarse straining and pre-ozonation, and water from the City's Aquifer Storage and Recovery (ASR) Surface Water Treatment Plant (SWTP). Water from the ASR SWTP originates as surface water and treats it with membrane ultrafiltration followed by an advanced oxidation process. The new NWWTF shall be designed to treat the Equus Beds Wellfield, Cheney Reservoir, ASR, and any combination to meet or exceed anticipated drinking water standards.

This technical memorandum provides a summary of process selection, proposed process design criteria, recommendations, and site layout. Process selection includes a summary of potential process alternatives, as well as a comparison of alternatives suited for the raw water quality provided.

SECTION 2 PROCESS ALTERNATIVES

A summary of raw water qualities and finished water treatment goals are shown in Table 1 below. Matching current corrosion control indices is a priority as to not induce corrosion or instability in the distribution system.

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Table 1 – NWWTF Raw Water Quality and Treatment Goals

Parameter	Goal	Regulatory Limit	Raw Water Quality (Untreated)						
			Surface Water (Cheney)			Groundwater (EBWF)			ASR
			Min	Max	Typ	Min	Max	Typ	Typ
Combined Filter Effluent Turbidity (NTU)	≤ 0.05 for 95% of readings Not to exceed 0.3	<1.0	3.03	20	15	2.15	10.3	4.9	0.17
Individual Filter Effluent Turbidity (NTU)	≤ 0.06 for 95% of readings; Not to exceed 0.3	≤ 0.3 for 95% of readings; Not to exceed 0.5							
Manganese (mg/L)	< 0.005	SMCL = 0.05	*0.044*			*0.296*			*<0.01*
Iron (mg/L)	< 0.1	SMCL = 0.3	ND	0.7	0.2	0.2	1.2	0.5	*0.01*
Total Hardness (mg/L as CaCO3)	≤ 120	N/A	150	210	174	220	285	285	236
pH (s.u.)	8.0 - 8.5	N/A	7.8	8.1	7.95	7.3	7.41	7.3	8.02
Alkalinity (mg/L as CaCO3)	> 80	Lead and Copper Stability	154	189	180	200	236	219	190
Total Organic Carbon (TOC) (mg/L)	> 35% removal	≥ 35% removal	--	5.9	5.02	--	1.19	0.7	5.05
Dissolved Organic Carbon DOC (mg/L)	> 10% Reduction	---	*4.73*			*1*			*5.05*
Raw or Finished Water SUVA (L/mg-m)	< 2	≤ 2 (alternative TOC compliance)	N/A			N/A			N/A
Bromate (μg/L)	< 5	≤ 10	N/A			N/A			N/A
TTHM LRAA (μg/L)	< 40	< 80	N/A			N/A			N/A
HAAS LRAA (μg/L)	< 30	< 60	N/A			N/A			N/A
Arsenic (μg/L)	< 1.0	≤ 10	*<50*			*<50*			*<50*
Lead (μg/L)	< 0.1	< 15	*<10*			*<10*			*<10*
Copper (μg/L)	< 10	≤ 1300	*<50*			*<50*			*<50*

There are many treatment options available to achieve the proposed water quality goals, including conventional rectangular basins, upflow clarifiers, solids contact clarifiers, high-rate processes, and multiple options for filtration processes. Due to its individual characteristics, each source water supply can be more efficiently treated with a different combination of physical, chemical and operational components (as determined by water quality and overall chemical utilization). A “one-size-fits-all” approach for the NWWTF will not provide process efficiencies or operational flexibility to meet the finished water goals for all blending scenarios being considered.

2.1 Technology Screening and Selection

Multiple technologies for each step in the treatment process were evaluated. The initial step of coagulation/clarification/softening indicated that the best available technologies (BAT) would be solids contact clarifiers or conventional coagulation sedimentation processes. High rate clarification/softening processes add little benefit to the treated water quality and adds operational complexity. The use of ion exchange for softening was not considered as other treatment processes are better suited for large scale water treatment facilities and do not generate large volumes of salt brine required to be disposed.

The use of a membrane process for either softening (reverse osmosis) or filtration (ultrafiltration) was considered but ultimately not selected. Reverse osmosis (RO) effectively softens the water but requires microfiltration/ultrafiltration (MF/UF) pretreatment prior to remove suspended particles which damage RO membranes and meet the surface water treatment regulations for *Giardia* and *Cryptosporidium* removal. Additionally, RO would require an additional 12 - 15 percent more water supply, which also translates into 12 to 15 percent brine (approximately 1,500 to 2,000 mg/L total dissolved solids) disposal. The capital and operating costs for RO are high compared to other technologies for this location and blending scenarios.

The use of MF/UF would provide filtration and would help meet the City’s finished water quality goals; however, the use of granular media filtration allows for the filters to become biologically active by replacing media with GAC in the future. Biologically active filters remove additional organic contaminants, which reduces the disinfection byproduct formation potential. Other benefits for biofiltration include removal of taste and odor compounds, enhanced finished water quality, and additional removal of assimilable organic carbon (AOC) to reduce biofilm growth when treating surface water with preozone (i.e. Cheney Reservoir and ASR SWTP). For this reason, granular media filters were selected instead of MF/UF.

2.2 Primary Treatment Approach

The differences in groundwater and surface water quality, specifically total organic carbon (TOC), hardness, alkalinity, and turbidity, suggests that providing different treatment processes with the BAT for each water supply. As such, solids contact clarifiers (SCCs) will be used to lime soften the waters and a conventional approach with ferric sulfate coagulation will provide improved TOC removal of the surface water. Blending water from the two treatment processes before filtration maximizes TOC removal and reduces chemical use and solids production.

2.3 Operational Approach

The NWWTF will be designed to operate three treatment trains in parallel. Process Train #1 consists of three SCCs rated at 20 MGD each and will be utilized primarily for GW treatment. Lime, ferric sulfate, and polymer will be dosed at the SCCs for softening, flocculation, and sedimentation of GW.

Process Train #2 consists of two additional SCCs rated at 20 MGD each and can be used to treat GW, SW, or a GW/SW blend. Similarly, lime, ferric sulfate, and polymer will be fed to Process Train #2 SCCs.

Process Train #3 includes three conventional rectangular basins with rapid mix, flocculation, and sedimentation rated at 20 MGD each. Process Train #3 will be primarily used for surface water treatment; however, GW/SW blends may be treated in these basins during peak production. Ferric and polymer will be dosed at the rapid mix prior to each conventional train.

SECTION 3 DESIGN CRITERIA

3.1 Regulatory and Code Requirements

The design criteria comply with Kansas Department of Health and Environment (KDHE) Policies, General Considerations and Design Requirements for Public Water Supply Systems in Kansas, 2008.

3.2 Headworks

The headworks area of the NWWTF will consist of flow metering and pressure reduction for both the Equus Beds Wellfield and Cheney Reservoir supplies. Additionally, mussel shell removal will be provided on the Cheney Reservoir supply line.

3.2.1 Flow Metering

Each raw water supply will be metered separately. Flow meters will be located in meter vaults outside of the headworks building. Each metering station will include manual bypass piping and other appurtenances to facilitate maintenance.

3.2.2 Pressure Reduction

Pressure reduction on the raw water feed piping will be required as both sources will be delivered at much higher pressures than required. Each supply will have its own pressure reduction valve inside the headworks building which will reduce pressures by approximately 45 psi depending on the supply source, flow, and blend between sources. PRVs will likely either be sleeve-type valves or plunger-type valves and will include bypass piping and other equipment to facilitate maintenance.

It was also considered to add a hydroelectric generation system at the headworks of the plant to both reduce pressure and generate electricity for the facility. Due to capital costs, this feature will not be added initially but the headworks building and piping will be designed to accommodate hydroelectric power generation in the future.

3.2.3 Mussel Shell Removal System

A vortex style system will be installed to remove mussel shells that are transmitted through the Cheney pipeline. It is desirable to capture shells upstream of the treatment processes to reduce the risk of damaging equipment or causing process upsets. The Cheney raw water line will direct flow to a vortex style unit that separates and dewaters grit while disposing into a dumpster. A raw water bypass will be installed to bypass the vortex system for maintenance and replacement purposes.

Table 2 – Mussel Shell Removal Design Basis

Design Flow	80 MGD
No. of Trains	2
Max. Headloss through Vortex	<0.02 ft
Max. Headloss through Complete Removal System	<3.1 ft
Minimum Removal Efficiency (Larger than 140 mesh)	95%
Drive Type	Mechanical

3.3 Rapid Mix

A well-designed mixing system is a critical link in the coagulation process. The goal of rapid mix is to disperse and completely mix the coagulation chemicals throughout the water as quickly as possible using high intensity mixing. The KDHE design guide indicates to provide optimal rapid mix conditions by requiring a near instantaneous mix followed almost immediately by flocculation. A well-operating rapid mix will provide high mixing energy and deliver the water to the flocculation zone in less than 30 seconds. After that, flocculated particles will start to form, and any mixing or shear stress that could be provided in long mixing time or long pipelines will break up the coagulated particles into small pin-flocs, resulting in inefficient settling and the likelihood of poor-performing sedimentation basins.

It is recommended that the City use a flash mix system with mixing energy (G-value) of 800 s^{-1} to inject ferric sulfate with polymer being added immediately upstream of the flocculators. Carbon dioxide will be added prior to the flash mix system to maintain the pH of approximately 6.8 – 7.0 to achieve enhanced coagulation and improved TOC reduction. Having the ability to add carbon dioxide and lime provides operators control of pH and alkalinity in the distribution system to manage finished water stability parameters.

Each rapid mix system will include a small pump skid operated with variable-frequency drives (VFDs) to recycle about three percent of each basin's flow and inject ferric sulfate countercurrent into the raw water line through a special nozzle. This type of system not only provides a high level of mixing and control of the mixing energy, even at low flows, but also has minimal headloss compared to other mixing alternatives.

3.4 Process Train #3 - Flocculation and Sedimentation

Process Train #3 is designed to treat surface water from the Cheney Reservoir. The treatment process includes flocculation and sedimentation as follows.

3.4.1 Flocculation

The flocculation process aids in creating large, dense, easily-settled particles. The aggregation of optimum size floc requires mixing intensity (velocity gradient, G) between 25 and 100 sec-1 for approximately 30 minutes in the summer months and 45 minutes in the winter months. Typically, the first stage of flocculation is operated at mixing intensity between 70 and 80 sec-1 with additional stages operating at two thirds and one third of this value. The mixing intensity can be varied by either installing flocculation equipment with variable speed drives or by adding or removing sections of paddles from constant speed flocculators. If the velocity gradient is too great, the shear forces will prevent the formation of a large floc. If the velocity gradient is insufficient, adequate inter-particle collisions will not occur, a proper floc will not develop and/or floc could settle out too quickly.

Table 3 – Flocculation Basin Design Basis

Design Flow	60 MGD
No. Flocculation Basins	3
Individual Flocculation Basin Flow	20 MGD
Flow Through Velocity	1.79 ft/min
Hydraulic Retention Time	30 min
Three (3) stage flocculation (65 ft (W) X 50 ft (L) X 16 ft SWD)	10 min each stage
Horizontal Mixers	
Stage 1 Mixing Intensity	G = 80 sec^{-1}
Stage 2 Mixing Intensity	G = 40 sec^{-1}
Stage 3 Mixing Intensity	G = 20 sec^{-1}

3.4.2 Sedimentation

Sedimentation is an important step in conventional treatment in the delivery of water of high clarity and turbidity in the finished water. The ideal design of a settling basin provides a sufficient path length for a particle to settle by gravity before the inertial forces carry it from the basin to the next process. Plate settlers will be added to the sedimentation basin to aid in settling which also decreases the overall footprint of the basin. Properly settled water results in long filter runs, reduced backwash wastewater volume, and improved finished water turbidities.

Table 4 – Sedimentation Basin Design Basis

Design Flow	60 MGD
No. Sedimentation Basins	3
Individual Sedimentation Basin Flow	20 MGD
Flow Through Velocity	1.79 ft/min
Hydraulic Retention Time	90 min
Sedimentation Rise Rate	1.34 gpm/sf
Each Sedimentation Basin (65 ft (W) X 160 ft (L) X 16 ft SWD)	1.245 MG
Basin Length to Width Ratio	2.5:1.0

3.5 Process Train #1 & 2 - Solids Contact Clarifiers

Solids contact clarifiers are frequently utilized at WTPs that perform softening treatment on groundwater. This type of equipment is much more effective for softening than the conventional treatment due to the provision of solids recirculation and maintenance of an adequate sludge blanket.

The purpose of using a solids contact clarifier is effective hardness and TOC removal utilizing precipitation in combination with aggregation or growth of the floc by solids recycle in the center cone. The water, after combining with previously generated solids in the basin, flows beneath the cone of the solids contact clarifier and into the sedimentation portion. The sedimentation portion of the basin provides solids/liquid separation and the water flows through orifices or over weirs in radial launders before being collected in a center or peripheral launder.

Solids collect at the bottom of the basin and are raked to the center of the basin using circular sludge collection rakes. The recirculated solids provide the source water and fresh lime with which to react and produce easily settable floc. The solids beneath the center cone of the solids contact clarifier are critical to the successful operation of the basin. These solids should range from 6 to 12 percent by volume beneath the center cone of the clarifier. Internal recirculation is typically 5 to 10 times the design flowrate.

Table 5 – Solids Contact Clarifier Design Basis

Design Flow	
Train #1 - Groundwater Supply Only	60 MGD
Train #2 – Groundwater, Surface Water, or blend	40 MGD
Individual Solids Contact Unit Design Capacity	20 MGD
Total No. Solids Contact Units	
Process Train #1	3
Process Train #2	2
Hydraulic Loading Rate	1.75 gpm/sf
Basin Diameter	115 ft
Basin Sidewall Depth	20 ft

3.6 Recarbonation

Lime softening will increase the water pH to allow hardness reduction through precipitation mechanisms. Carbon dioxide will be used to reduce the pH after lime softened to 8.0 to 8.5. This will provide a stable water quality to minimize deposition of lime scale on the filters, downstream processes, and distribution system.

Recarbonation will be achieved using a pressurized solution feed (PSF) system. A PSF system is designed to utilize 95% of the CO2 gas to reduce the pH. This is accomplished by forcing CO2 gas into a solution under high pressure and forcing this gas to remain in solution until injected into the water to be treated. The carbonated solution, which is now carbonic acid and excess CO2, is injected into the water stream under pressure. The excess CO2 gas, if any, is released as an effervescence, which is immediately consumed by the water being treated. The chemical reaction time is only 60 to 90 seconds from the point of injection to the point of measurement for pH control.

Liquid carbon dioxide is stored in a bulk storage tank. The liquid carbon dioxide is vaporized and pressure fed to a carrier water, forming the carbonic acid. The carbonic acid is then fed as a liquid acid to the water. A pH controller located 60 to 90 seconds downstream is used to manage the carbon dioxide feed system to maintain a consistent water pH. Design criteria for the CO2 system is provided later in this memorandum in the chemical feed section.

3.7 Filtration

Filtration will be accomplished with dual media filters consisting of sand and anthracite; however, the filters and associated processes will be designed to accommodate future biological filtration. Biological filtration (biofiltration) is the operational practice of managing, maintaining, and promoting biological activity on granular media in a filter to enhance the removal of organic and inorganic constituents before treated water is introduced into the distribution system. An engineered biofilter integrates microbial parameters with the hydraulic and water quality parameters of traditional granular media filters. Biofilters can assist in the removal of organic carbon, taste and odor compounds, such as MIB and geosmin, removal of other contaminants of emerging concern (CECs), and provide biological stability downstream of ozone injection to limit distribution system regrowth potential.

3.7.1 Filters

The filter design is based on two independent sets of filters with each set of filters designed to provide 60 MGD with the largest filter out of service. Ten filters will be located in each filter bay. Water from the three process trains is blended to a uniform quality prior to entering the filters.

Filters will include filter-to-waste provisions and effluent turbidity monitoring. With proper pretreatment operation of the solids contact and conventional clarifiers, the filter will produce water turbidity less than 0.1 NTU with filter run times up to 80 hours.

Turbidimeters will be provided on each individual filter. Managing the combined filter performance to produce turbidity less than 0.15 NTU in 95 percent of samples, allows for 0.5-log Cryptosporidium removal credits. Additionally, operating the individual filters less than 0.15 NTU in 95 percent of samples allows for an additional 0.5-log Cryptosporidium removal credits. The additional 1.0-log Cryptosporidium removal credit provides a benefit if the Cheney Reservoir source is every re-classified as a LT2ESWTR Bin 2 source, this facility will remain in compliance with no changes necessary.

Table 6 – Filter Design Basis

Design Flow		120	MGD
Reliability		N+2*	
Note: * Operate two (2) separate sets of filters. Each set designed for N+1			
Filter Loading Rate (maximum)		4	gpm/sf
Filter Area per Filter		1,176	sf
Total Number of Filters		20	
Filter Box (inside dimensions)			
Length		42	ft
Width		28	ft
Length to Width Ratio		1.5 to 1	
Filter Media			
Sand	d_{10} = 0.4 mm, UC = 1.4	12	in
Anthracite**	d_{10} = 1.2 mm, UC = 2.0	60	in
Empty Bed Contact Time for Granular Activated Carbon**		9.5	min
**future GAC design with biological filtration			

3.7.2 Filter Wetwell Pumping to Finished Water Storage with Chlorine Contact

The hydraulic profile shows that gravity flow from the filters to finished water storage is not possible. As a result, a wetwell is required to pump filtered water and will be located immediately under the filter effluent collection system. System pumps will be sized to match filter flow rate using a combination of 10, 20, and 30 MGD pumps summarized in the table below. Variable frequency drives will allow flows increments less than 10 MGD.

Table 7 –Filter Wetwell Pump Station Design Basis

Design Head			40 ft	
Pump Efficiency			80%	
Motor Efficiency			96%	
Total No. Pumps	Q (MGD)	Total Flow	Firm No	Firm Capacity
3	10	30	3	30
3	20	60	3	60
2	30	60	2	30
	Total	150		120
Total Connected Capacity	150 MGD		1,370 BHP	
Firm Capacity	120 MGD		1,096 BHP	

3.7.3 Backwash Requirements

Backwashing is an indispensable part of rapid filtration. Improper, inadequate, or too much backwashing are some of the most frequent causes of problems in filters. Filter backwash incorporates both air/water wash and a water only wash sequences. The air scour provides the vigorous agitation of the bed and causes collisions and abrasions between media grains that break deposited solids loose. Once the solids are separated, the backwash water can flush the solids from the filter.

Table 8 – Filter Backwash Design Basis

Backwash Water Source	Finished Water Storage Reservoirs			
Filter Bed Expansion	40-50%			
Backwash Flow Rates - Water Only				
Water Temperature = 5°C	20,460	gpm	17.4	gpm/sf
Water Temperature = 25°C	28,100	gpm	24.9	gpm/sf
Backwash Flow Rates – During Air/Water Wash				
Water Temperature = 5°C	5,410	gpm	4.6	gpm/sf
Water Temperature = 25°C	7,430	gpm	6.3	gpm/sf
Blower for Air Scour	5,880	scfm	5.0	scfm/sf

3.7.4 Backwash Waste Equalization Basin and Recycle Pumping

Backwash waste will be collected in an equalization basin. As the backwash water enters the equalization basin, a backwash recycle pump will begin to return water to the plant headworks. The recycle rate is designed to be no more than 10 percent of the raw water flow rate.

While it is anticipated that filter run times will be approximately 80 hours, a 60-hour filter run time was used to prevent the backwash equalization basin from becoming a bottle neck in the plant production during difficult operating periods, such as a softening or settling basin upset.

Table 9 – Backwash Equalization Basin and Recycle Pumping Design Basis

Design Head	25 ft	
Pump Efficiency	80%	
Motor Efficiency	96%	
Total Number Filter Backwashes per Day	8	
Design Backwash Time per Filter	15	min
Time Delay between Filters being Backwashed	15	min
Backwash Volume		
per Filter	441,000	gal
Total/day	3,528,000	gal
Maximum Recycle (assumed less than 10% Raw Water Flow)	8,333	gpm
Backwash Waste Equalization Basin		
Volume	1.53	MG
Maximum Water Depth	18	ft
Footprint Area	11,400	sf
Recycle Pumping (Return backwash water to plant headworks)		
Quantity	2	
Design Flow	8,333	gpm
BHP (each)	75	HP

3.7.5 Filter-to-Waste Equalization Basin and Recycle Pumping

Filter-to-Waste is required to gravity flow out of filters similar to normal operations. Typically, filter-to-waste water would be collected in the backwash equalization basin; however, due to the hydraulic profile, the filter-to-waste equalization basin will collect filter-to-waste water, which will be recycled to the plant headworks. A separate filter-to-waste equalization basin will be provided for each set of 10 filters.

Table 10 – FTW Equalization Basin and Recycle Pumping Design Basis

Total Number Filter Backwashes per Day	8	
Design Filter-to-Waste Time per Filter	30	min
Time Delay between Filters operating Filter-to-Waste	25	min
Filter-to-Waste Volume		

per Filter	70,560	gal
Total/day	564,480	gal
Filter-to-Waste Equalization Basin		
Volume	0.25	MG
Maximum Water Depth	5	ft
Quantity	2	
Footprint Area (each)	3,340	sf
Recycle Pumping (Return filter-to-waste water to plant headworks)		
Quantity (N+2)	4	
Design Flow (FTW pumping no longer than 9 hours)	1,260	gpm

3.8 Finished Water

3.8.1. Finished Water Storage and Disinfection

Finished water storage will be provided using one prestressed concrete reservoir set at grade, with a center portion dedicated for chlorine contact. The reservoir will be 20-MG capacity (300 ft diameter, 38 ft depth) including the chlorine contact chamber, which will be designed with a baffling factor of 0.7. Primary disinfection will be accomplished using free chlorine with ammonia added to form chloramines for secondary disinfection. Primary disinfection will provide for 0.5-log Giardia inactivation and 2.0 log inactivation for viruses to meet the requirements defined in the Interim Enhanced Surface Water Rule (IESWTR).

3.8.2 Low Service Pump Station

The Low Service Pump Station will deliver finished water to the Hess Reservoir system. The Hess Reservoir system provides storage and high service pumping to the city's distribution system. The Low Service Pump Station will have the capability to pump any flow rate from 30 MGD to 150 MGD to meet peak day demand. The 10 MGD pumps include variable frequency drives to allow flow increments less than 10 MGD.

Table 11 – Low Service Pump Station Design Basis

Design Head		25 ft (10.8 psi)
Pump Efficiency		80%
Motor Efficiency		96%
Quantity	**Capacity (MGD)**	**BHP (ea)**
2	10	57
2	20	114
3	30	171
Total Connected Capacity	150 MGD	856
Firm Capacity	120 MGD	685

3.9 Chemical Feed

Chemical feed to Process Trains #1 and #2 includes lime, ferric sulfate, and polymer. Chemical feed to Process Train #3 includes ferric sulfate, polymer and carbon dioxide. Carbon dioxide will be fed to the blended water from the three process trains to stabilize the water before filtration. Polyphosphate/orthophosphate will be fed for lead corrosion mitigation, sequestering, and to maintain the corrosion control/saturation indices.

Primary disinfection includes free chlorine feed before the chlorine contact basin. Secondary disinfection will include chlorine and ammonia for chloramine formation.

The lime, ferric sulfate, and polymer storage and feed rooms will be housed in a single building, with distinctly separate storage and feed rooms for each chemical. This building will be located near the solids contact clarifiers and conventional treatment basins, as shown in the attached site layout. The CO2 storage will be located adjacent to the chemical storage building and feed will be housed in a separate building near the solids contact clarifiers and conventional treatment basins.

Anhydrous ammonia and chlorine gas will be housed in a single building, with distinctly separate storage and isolated feed rooms for each chemical.

3.9.1 Lime

Lime will be provided for water softening of raw groundwater and for pH adjustment of blended water. A summary of the chemical dosing locations and concentrations are provided in the table below:

Table 12 - Lime Dosing Summary

Characteristic	Units	Process Train			Settled Water Blend
		#1	#2	#3	
Max Daily Flow	MGD	60	40	60	140
Avg Daily Flow	MGD	35	0	35	70
Min Daily Flow	MGD	15	20	15	30
Max Dose	mg/L as $Ca(OH)_2$	180	180	0	30
Design Dose	mg/L as $Ca(OH)_2$	130	100	0	10
Min Dose	mg/L as $Ca(OH)_2$	50	10	0	0

To incorporate reliability and adequately encompass the split flow and high lime demand conditions at the NWWTF, the implementation of multiple slakers was considered during design.

To improve efficiency of lime usage and provide a higher quality lime to the process, a N+1 batch slaker system will be implemented. The batch lime slaking system will consist of the following major equipment components:

- 4 lime silo bin adapters and bin vibrators;
- 3 screw conveyor lime feeders (2 duty, 1 standby);
- 3 batch slaker tanks (2 duty, 1 standby);
- 3 grit classifiers (2 duty, 1 standby);
- 3 slurry aging tanks (2 duty, 1 standby);
- 9 slurry loop pumps (2 duty and 1 standby for each slaker)
- 9 slurry loops (2 duty and 1 standby for each slaker);
- 10 slurry dosing assemblies (1 for each dosing location and appropriate standby); and
- System control panels.

The four lime silos will be capable of storing 14,000 cubic feet of dry lime to retain 35 days of storage at average daily dose and flow. The dosing locations include upstream of the two blended stream rapid mix basins, upstream of the three groundwater stream rapid mix basins, and at the settled water blending structure. Three dosing locations, at the Process Train #3 rapid mix basins, will be available for use, only as necessary; however, it is anticipated that lime will not be dosed in Process Train #3 during normal operation.

The slurry dosing assemblies will be connected to the continuously pumped slurry loops and will be located near each lime injection point to meter chemical according to the operator selected dose for that location. These assemblies will be flow-paced. The slurry dosing assemblies will be sized to apply a dosing range from the minimum concentration and minimum flow rate to the maximum concentration and maximum flow rate of each dosing location.

3.9.2 Ferric Sulfate

The KDHE minimum design standards for ferric sulfate, specifically include, but are not limited to, "Acids and caustics shall not be handled in open vessels but should be pumped in undiluted form from original containers through suitable hoses, to the point of treatment or to a covered day tank."

Ferric sulfate will be dosed as a coagulant to assist in removal of organics and solids settling. A summary of the chemical dosing locations and concentrations are provided in the table below:

Table 13 - Ferric Sulfate Dosing Summary

Characteristic	Units	SW Stream	(GW or SW)	GW Stream
Max Daily Flow	MGD	60	40	60
Avg Daily Flow	MGD	35	0	35
Min Daily Flow	MGD	0	20	0
Max Dose	mg/L as $Fe2(SO4)3$	50	50	50
Design Dose	mg/L as $Fe2(SO4)3$	30	10	10
Min Dose	mg/L as $Fe2(SO4)3$	1	1	1

The ferric sulfate dosing system will consist of the following major equipment components:

- 3 - 15,000-gallon bulk storage tanks (located indoors);
- 1 - 3,000-gallon day tank; and
- 11 feed pumps (1 pump for each dosing location and appropriate standby).

The three bulk storage tanks would be capable of storing 30 days of ferric sulfate at average day flow and average dose. A 3000-gallon day tank will be provided sized for all dosing locations. Each of the eight clarification units will have a dedicated feed pump and three transfer pumps. Each treatment stream will have one redundant or swing pump. The feed pumps will be skidded peristaltic pumps. The feed pumps will be flow-paced. The feed pumps will be sized to apply a dosing range from the minimum concentration and minimum flow rate to the maximum concentration and maximum flow rate of each dosing location.

3.9.3 Polymer

The minimum design standards for polymer, specifically include, but are not limited to, "A cationic or nonionic liquid polymer solution will be utilized for settling and as a filter aid."

A summary of the chemical dosing locations and concentrations are provided in the table below:

Table 14 - Polymer Dosing Summary

Characteristic	Units	SW Stream	(GW or SW)	GW Stream	Filter Aid
Max Daily Flow	MGD	60	40	60	140
Average Daily Flow	MGD	35	0	35	70
Min Daily Flow	MGD	15	0	15	30
Max Dose	mg/L	3	3	3	2

Design Dose	mg/L	1	1	1	1
Min Dose	mg/L	0.1	0.1	0.1	0.1

The polymer dosing system will consist of the following major equipment components:

- 2 - 1,500-gallon bulk storage tanks (located indoors);
- 1 - 200-gallon day tank; and
- 13 feed pumps (1 pump for each dosing location and appropriate standby).

The two bulk storage tanks would be capable of storing 31 days of polymer at average day flow and average dose. A 200 gallon day tank will be provided sized for all dosing locations. The polymer will be fed to all eight rapid mix basins, as well as to the settled water blending structure as a filter aid. Each of these dosing locations will have a feed pump and one redundant feed pump will be supplied for each treatment stream (i.e. one for each Process Train). The feed pumps will be skidded peristaltic pumps. The feed pumps will be flow-paced. The feed pumps will be sized to apply a dosing range from the minimum concentration and minimum flow rate to the maximum concentration and maximum flow rate of each dosing location. Carrier water will be utilized to facilitate pumping of these chemicals to the dosing locations.

3.9.4 Polyphosphate

Polyphosphate/orthosphosphate will be used for corrosion control and sequesting and will be dosed upstream of the filters. A summary of the design criteria for polyphosphate is provided in the table below:

Table 15 - Polyphosphate Dosing Summary

Characteristic	Units	Pre-Filters
Max Daily Flow	MGD	140
Average Daily Flow	MGD	70
Min Daily Flow	MGD	30
Max Dose	mg/L	2
Design Dose	mg/L	1
Min Dose	mg/L	0.1

The polyphosphate dosing system will consist of the following major equipment components:

- 2 - 1,500-gallon bulk storage tanks (located indoors);
- 1 - 100-gallon day tank; and

- 2 feed pumps (1 duty/1 standby).

The two bulk storage tanks would be capable of storing approximately 60 days of polymer at average day flow and average dose. A 100 gallon day tank will be provided to accommodate a max 24 hr feed rate. The polymer will be fed just upstream of the filters, in the settled water blending structure. The feed pumps will be skidded peristaltic pumps and will be flow-paced. The feed pumps will be sized to apply a dosing range from the minimum concentration and minimum flow rate to the maximum concentration and maximum flow rate of each dosing location. Carrier water will be utilized to facilitate pumping of these chemicals to the dosing locations.

3.9.5 Carbon Dioxide

Carbon dioxide will be utilized at the NWWTF for pH adjustment prior to conventional treatment in Process Train #3 and stabilize the blended waters from all operating process trains at the settled water blending structure, prior to filtration.

A summary of the chemical dosing locations and concentrations are provided in the table below:

Table 16 - Carbon Dioxide Dosing Summary

Characteristic	Units	SW Stream	Settled Water Blending Structure
Max Daily Flow	MGD	60	140
Average Daily Flow	MGD	35	70
Min Daily Flow	MGD	15	30
Max Dose	mg/L	15	20
Design Dose	mg/L	5 to 10	15
Min Dose	mg/L	1	1

Pressurized solution feed systems will be used. In this method, carbon dioxide gas is injected into a pressurized sidestream of finished water to create a carbonic acid solution. This solution is then injected into the process stream, allowing for quick mass transfer to occur due to the high pressure and the liquid-to-liquid interaction. Due to the quick transfer and use of a liquid solution, this method allows for application directly into a pipeline, without requiring a deep basin or additional mixing. This system typically has a high degree of mass transfer efficiency, leading to more efficient usage of the carbon dioxide gas; however, a fairly large amount of water is required for the pressurized sidestream.

The pressurized solution feed system will consist of the following major equipment components:

- 2 - 100,000 lb bulk storage tanks;
- 6 feed systems (1 for each dosing location and appropriate standby).

The two bulk storage tanks would be capable of storing 41 days of carbon dioxide at average day flow and average dose. There will be six feed systems, with one duty system for each of the two surface water splitter structure influent pipes, as well as one duty system for each of the two settled water blending structure influent pipes. One standby feed system will be used as a swing pump for both splitter structure feed systems and one standby will be used as a swing pump for both settled water blending structure feed systems. The feed pumps will be sized to apply a dosing range from the minimum concentration and minimum flow rate to the maximum concentration and maximum flow rate of each dosing location. The feed systems will be flow paced and dosages will be determined based on pH. Diffusers are utilized to inject the carbon dioxide gas into the process. The diffuser for the surface water splitter structure will be located at the influent pipe for splitter structure. The diffuser at the settled water blending structure will be located within the influent pipe.

3.9.6 Disinfection Chemicals

Disinfection of the treated drinking water at the NWWTF will be performed via chloramination. Chloramines are currently used at the Main WTP because the residual can be maintained through large distribution systems and they produce fewer disinfection by-products than traditional chlorination. Chloramines are formed from the chemical reaction between chlorine and ammonia compounds. For drinking water disinfection, a ratio of chlorine to ammonia dose should be around 4:1 to favor monochloramine formation while avoiding formation of other chloramine species that would not provide disinfectant properties.

A comparison of chlorine feed options was performed to guide discussions that would allow the City to decide on a preferred method that would provide the most reasonable public safety, personnel safety, and economy. Details of this comparison are provided in Section 3.9.6.1 below. Anhydrous ammonia will be provided for the ammonia feed and details are provided in Section 3.9.6.2 below.

The KDHE Minimum Design Standards for Public Water Supply for general chemical feed listed in other sections of this memorandum also apply to the disinfection chemical feed design detailed in this section.

3.9.6.1 Chlorine

Chlorine will be fed prior to the chlorine contact chamber for primary disinfection and combined with ammonia after finished water storage to form chloramines for distribution residual. A summary of the chlorine dosing locations and concentrations is provided in the table below:

Table 17 – Chlorine Dose Requirements

Characteristic	Units	Pre-Reservoir	Post-Reservoir
Max Daily Flow	MGD	140	140
Average Daily Flow	MGD	70	70
Min Daily Flow	MGD	30	30
Average Dose	mg/L	2	4

Capital and operations and maintenance costs were compared for multiple chlorination methods including onsite hypochlorite generation, bulk liquid sodium hypochlorite delivery, and various forms of chlorine gas. During the February 6, 2018 project progress meeting, the comparison was presented to the City for discussion and selection. The City considered the system operations, safety, and costs and selected six 10-ton chlorine gas storage tanks with all safety considerations included as the preferred option.

This option provided enough tanks to have uninterrupted feed during delivery, minimized handling requirements in comparison to one-ton cylinders, and optimized air scrubber size. The 10-ton tank, feed system will consist of the following major equipment components:

- 6 – 10-ton bulk storage tanks (30 days storage);
- 6 – 2-ton scrubbers
- 6 evaporators;
- 2 feed systems for dosing prior to the contact basin (1 duty; 1 standby);
- 2 feed systems for dosing after the contact basin (1 duty; 1 standby).

3.9.6.2 Anhydrous Ammonia

Anhydrous Ammonia will be used at the NWWTF to produce chloramines for distribution residual, when added to chlorinated water. A summary of the ammonia dosing locations and concentrations are provided in the table below:

Table 18: Ammonia Dosing Summary

Characteristic	Value	Units
Max Daily Flow	140	MGD

Average Daily Flow	70	MGD
Min Daily Flow	30	MGD
Average Dose	1	mg/L

The vacuum solution feed system will consist of the following major equipment components:

- 5 - 2000-gallon bulk storage tanks;
- 2 feed systems for dosing after the chlorine contact basin (1 duty; 1 standby)

The bulk storage tanks are capable of storing 70 days of ammonia at average day flow and average dose. The excess storage is provided to allow for delivery one full tanker volumes, approximately 7,000 gallons, as well as storage to be filled to a maximum of 85-percent of the tank volume. There will be two feed system; one duty and one standby system will be provided. The feed systems will be flow paced. Diffuser will be utilized to inject the ammonia into the process within the chlorine contact basin structure. Mixing will be provided by effluent pipe turbulence.

3.10 Solids Handling

The solids generated from the solids contact clarifiers and conventional clarifiers will be directed to gravity thickeners. The thickened solids will be pumped to the City's existing sludge lagoons with ultimate disposal as beneficial use on agricultural lands.

The conventional treatment (Train 3) sludge is made up of the suspended material from the Cheney Reservoir, ferric hydroxide, and a large amount of bound and entrapped water in a loose structure. The raw water suspended materials include clay and other sediment particles, algae, organic compounds and colloids, and other similar materials. Ferric sludges are not as easily dewatered as lime. Addition of polymer in the thickening process often forms the particle bridges necessary to improve settleability. Additionally, blending with lime sludges can aid in settleability.

Lime solids are dense and settle rapidly with solids concentration as high as 15 percent dry solids. The higher solids concentration is anticipated when treating groundwater only in the solids contact clarifiers. Solids concentrations in this range will not require thickening and the lime sludge may be pumped directly to the sludge lagoons.

Gravity thickeners are proposed for the NWWTF. Gravity thickeners are generally circular settling basins with a scraper mechanism in the bottom. The thickeners may be operated as continuous flow or as a batch fill-and-draw. The decanted water exits the thickener over a peripheral weir or trough. The thickened sludge is drawn off the basin. The scraper mechanism rotates slowly, directing the sludge to a draw-off pipe near the bottom, center of the basin. The slow rotation of the scraper mechanism also prevents bridging of the sludge solids. Two decant return pumps and two sludge pumps will be provided at full capacity for reliability.

Table 19: Sludge Thickening Summary

Design Plant Flow	140	MGD
Lime Solids Produced	126,500	lbs/day
Ferric Solids Produced	82,126	lbs/day
Total Solids Mass	208,627	lbs/day
Influent Flow	1,667	gpm
Influent Solids Concentration	0.52%	
Solids Loading	0.5	lbs/hr/sf
Hydraulic Loading	0.17	gpm/sf
Decant Pump Time	8	hrs/day
Decant Flow	4,400	gpm
Sludge Blowdown Time	4	hrs/day
Blowdown Flow to Lagoon	1,180	gpm
Blowdown Solids Concentration	8%	
Diameter	80	Ft
Quantity	2	

Table 20: Decant Return Pumps

Design Flow	4,400 gpm
Design Head	25 ft
Pump Efficiency	75%
Motor Efficiency	95%
Break Horsepower	39.0 BHP

Table 21: Sludge Pumping Summary

Design Flow	1,180 gpm
Design Head	50 ft
Pump Efficiency	50%
Motor Efficiency	95%
Break Horsepower	32.4 BHP

The final design of the gravity thickeners will be based either the hydraulic or solids loading as the primary design criteria. Field testing of the sludge is necessary to properly size the gravity thickeners. The values in Tables 19, 20, and 21 are based on textbook values and need to be validated during final design for various blends of ferric and lime solids with various polymers.

SECTION 4 SITE CONSIDERATIONS

4.1 Introduction

Site drainage is defined by the Kansas Southwestern Railroad to the west, Big Slough-Cowskin Creek Floodway to the east, and 21st Street North to the north. The total drainage area of 134 acres drains to an existing groundwater pond where water levels rise during storm events and recede to the natural groundwater table following. As a result of the proposed site development and an increase in impervious area, a drainage analysis was completed to assess site development impacts and the need for drainage related improvements. The City of Wichita adopted Storm Water Ordinances on January 1, 2011. These ordinances specifically include regulations regarding water quality, channel bank protection, and on-site detention for site development. Hydrologic and hydraulic stormwater analysis was performed in accordance with the City of Wichita Stormwater Manual and a Hydrologic Engineering Center – Hydrologic Modeling System (HEC-HMS) model was created to simulate storm events.

4.2 City of Wichita Requirements

The first requirement specified in the City Ordinances requires solids removal from any storm water flow leaving the project site. The solids, described as Total Suspended Solids (TSS), includes any sediment, debris, etc. that could become trapped in water. This requirement is known as Water Quality. The City of Wichita requires 80% TSS removal for 100% of new construction located on a virgin site. Per City regulations, water quality treatment is required when a project site disturbs 1 or more acres.

Channel Bank Protection is an additional requirement by the City of Wichita. This regulation is specific to more frequent storm events being the primary cause of downstream erosion. Efforts must be made to detain and control the release of water from these frequent annual storm events. The volume of runoff that results from the one-year 24-hour post development conditions must be detained for at least 24 hours. Channel bank protection is required when a project site disturbs five or more acres and discharges to an erodible stormwater conveyance.

The third requirement by the City of Wichita is on-site detention. Hydrologic analysis shall be completed to illustrate that peak runoff rates for varying storm events are not increased, or adversely affected, by the proposed site conditions in comparison to the existing site conditions. Per City regulations, on-site detention is required when a project site disturbs 1 or more acres but may be waived by the City if the proposed site includes less than 1 acre of new impervious area.

4.3 Hydrologic Analysis

Curve Numbers (CN), representing runoff potential, were generated for existing and proposed conditions. A United Stated Dept. of Agriculture (USDA) Web Soil Survey was conducted on the project area and the site consists of Soil Grade C. The existing site condition was considered 20% impervious represented by CN 98 with the remaining 80% considered as pasture, grassland, or range in good condition represented by CN 74; resulting in an existing conditions-weighted CN of 78.8. The proposed site condition was considered 60% impervious and 40% pasture, grassland, or range in good condition; resulting in a proposed conditions weighted CN of 88.4. A time of concentration (ToC) for the overall drainage basin was assumed as 60 minutes.

A HEC-HMS model was developed to calculate rainfall runoff and volume for various storm events (1-, 2-, 5-, 10-, 25- and 100-year 24-hour NRCS Type 2 distribution) for both the proposed and existing conditions utilizing data generated from site drainage characteristics. The modeling results are summarized in the table below.

Table 22: Peak Runoff Rates and Volumes

		Existing Conditions		**Proposed Conditions**	
Storm Event	Precipitation (IN)	Rate (CFS)	Volume (AF)	Rate (CFS)	Volume (AF)
1-Year	2.90	70.44	12.31	118.70	19.63
2-Year	3.39	95.87	16.36	148.48	24.56
5-Year	4.24	142.90	23.90	200.76	33.34
10-Year	4.98	185.78	30.84	246.50	41.14
25-Year	6.03	248.46	41.09	311.37	52.37
100-Year	7.83	358.39	59.37	422.07	71.89
500-Year	10.10	498.56	83.18	560.57	96.75

Peak runoff rates for the proposed condition will increase from the existing condition due to the increase in impervious area.

4.4 Detention and Stormwater Pump Station

An existing groundwater pit detention pond will be utilized for site detention as well as to address water quality and channel bank protection requirements. Stage storage information is provided in the table below and reflected on the grading plans. This information was utilized in detention routing analysis in HEC-HMS. Survey of the pond indicates a water surface elevation of 1308 ft. As the groundwater table is subject to fluctuations throughout the year, a static pond elevation of 1310 ft was assumed in modeling, representing a seasonal high groundwater table.

The top of pond bank was considered at elevation 1320 ft. Areas above 1320 ft include storage volume available in the emergency overflow channel to the southeast of the pond.

Table 23: Detention Pond Stage Storage

Detention Pond Stage Storage			
Elevation	**Area (AC)**	**Inc. Vol. (AF)**	**Total Vol. (AF)**
1308	6.18		
1309	6.57	6.37	6.37
1310	8.05	7.31	13.68
1311	8.34	8.19	21.88
1312	8.56	8.45	30.32
1313	8.72	8.64	38.96
1314	8.88	8.80	47.76
1315	9.04	8.96	56.71
1316	9.19	9.12	65.83
1317	9.44	9.32	75.15
1318	9.62	9.53	84.68
1319	9.80	9.71	94.38
1320	10.06	9.93	104.31
1321	20.51	15.28	119.59
1322	27.69	24.10	143.69

Due to the fluctuation of infiltration rates based on soil type and moisture content, a stormwater pump station is proposed to discharge stormwater during and after rain events to restore the available storage volume faster than natural infiltration. The proposed pump station for the pond consists of a total peak pumping capacity of 10,000 GPM pump (22.28 CFS) which will control up to the 500-year storm event with available freeboard to accommodate an emergency event (see Emergency Event Management section below). The pumps will include one duty and one standby to handle the peak flows. Pond pump station peak discharge rates and elevations are summarized in the table below.

Table 24: Peak Pond Elevations

Storm Event	Pond Elevation
1-Year	1311.19
2-Year	1311.59

5-Year	1312.27
10-Year	1312.90
25-Year	1313.76
100-Year	1315.39
500-Year	1317.57

Water quality requirements are met by the detention pond which is considered as a Best Management Practice that achieves 80% TSS removal.

Channel bank protection requirements will be met by the detention pond and pump station. A smaller, low flow pump will be considered with final design with the intent of delaying the discharge of the 1-year storm event more than 24 hours per City regulations.

Peak discharge rates are restricted to the pump station discharge of 22.28 CFS which is less than the existing condition for all storm events which adequately addresses detention requirements.

The site analysis discussed in this memo provides for 4.61' and 2.43' of freeboard from the top of pond bank 1320 ft elevation in the 100-year and 500-year events, respectively.

4.5 Emergency Event Management

In addition to the pump station, an emergency overflow will be set at elevation 1320 ft which will discharge to a proposed conveyance ditch along the east/southeast perimeter. The ditch will then discharge to a proposed reinforced concrete box culvert across Zoo Boulevard. The intent of the emergency overflow is to convey all site drainage, including emergency tank ruptures or line breaks, such that the critical facilities on the site are not flooded if pond capacity is exceeded by either pump station failure or a storm event exceeding the 500-year event.

The City of Wichita requested site drainage design to be based upon a site facility failure occurring simultaneously to the peak elevation of a 500-year storm event. The emergency event considered a 20 MG tank rupture, which equates to 61.4 acre-feet of water, being received by the detention pond simultaneous to the 500-year storm event peak elevation. The HEC-HMS model for this emergency event calculated a peak elevation of 1321.95 ft. This will provide for 3' of freeboard for site facilities which will have a minimum low opening elevation of 1325 ft; however, most on-site structures will be constructed with openings considerably above 1325 ft. due to process hydraulics and groundwater elevation.

SECTION 5 BACKUP POWER GENERATION

5.1 Overview

Electrical power will be delivered to the site by Westar from an on-site electrical substation. 12,470V utility feeds will be routed to the site main paralleling switchgear located in the 100' x 200' wind-rated Central Power Station. Three 2.25 MW 12,470V emergency standby diesel generators will be installed in this building along with the site main paralleling switchgear. The main paralleling switchgear will automatically control the generators and paralleling with the utility feeds during power outages and generator testing.

12,470V feeders will be routed throughout the plant campus in a loop configuration to increase redundancy and reliability. Local transformers will transform the site distribution voltage down to the local utilization voltage (typically 480V, high service pumps may be 5kV or higher).

5.2 Assumptions and Calculations

Generators were sized based on the estimated connected loads shown in the table below. Soft starts or VFDs were assumed for all motors 50HP and above. Startup sequence was assumed to be in the order shown below with approximately one half of the loads starting sequentially in the first pass and the second half of the loads in the second pass.

Table 25: Total Connected Loads

Process	Connected	
	BHP	KW
Low Service Pumping	856	638
Filter Wetwell Pumps	1,370	1,021
Backwash Supply Pumps	1,160	865
Air Scrubber Blower	486	362
Backwash Waste Recycle Pumps	150	112
Filter to Waste Recycle Pumps	42	31
Solids Contact Units	25	19
Flocculators	45	34
Sedimentation Basins	15	11
Vortex Mussel Removal	5	4
Thickeners	15	11
Other Loads	417	311
Total Connected	**4,583**	**3,417**